Predicting Tropical Cyclone Genesis

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LONG-TERM GOALS

The long-term goal of this project is to provide probabilistic tropical cyclone (TC) genesis forecast guidance to operational forecasters and use the genesis index to provide guidance for initializing a high-resolution mesoscale model prediction for tropical cyclone genesis. Once regions of high TC genesis probability are identified, the identified regions will be suggested for the use of a moving, multi-nested version of the COAMPS®[1]/TC with horizontal resolution of roughly 3 km or less in the innermost grid for the prediction of the genesis event.

OBJECTIVES

The objective of this project is to develop a TC genesis index that can provide the probability of tropical disturbances becoming tropical cyclones, based on predictions of numerical models such as NOGAPS (Navy Operational Global Atmospheric Prediction System).

[1] COAMPS® (Coupled Ocean/Atmosphere Mesoscale Prediction System) is a registered trademark of the Naval Research Laboratory. COAMPS®/TC is a specific version of the coupled system being developed for tropical cyclone prediction.

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14. ABSTRACT

The long-term goal of this project is to provide probabilistic tropical cyclone (TC) genesis forecast guidance to operational forecasters and use the genesis index to provide guidance for initializing a high-resolution mesoscale model prediction for tropical cyclone genesis. Once regions of high TC genesis probability are identified, the identified regions will be suggested for the use of a moving, multi-nested version of the COAMPS?1/TC with horizontal resolution of roughly 3 km or less in the innermost grid for the prediction of the genesis event.

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APPROACH

Our approach is to use previously identified characteristics associated with developing and non-developing disturbances for tropical cyclone formation and determine the most important atmospheric variables. A sophisticated regression method to combine all the information and construct TC genesis probability forecast models for different basins will be constructed and applied to NOGAPS forecast fields to provide TC genesis probabilistic predictions.

WORK COMPLETED

The research in this year is primarily focused on 1) adding more developing and non-developing cases from NOGAPS in 2006-2008 into our sample dataset that covers 2003-2008 periods and 2) applying the nonlinear logistic regression method in addition to the multiple linear regression method.

We have finished analyzing six years (2003-2008) of NOGAPS analysis data and obtained 85 developing and 451 non-developing disturbance sample cases in the western North Pacific (WNP). Based on the extended sample dataset, we reconstructed the composite of variables that are crucial for TC genesis. Some composite results will be presented in the following section.

We successfully switched our old multiple linear regression method to the nonlinear logistic regression method. A 24-hour TC genesis probability prediction model for the WNP was developed based on this updated sample dataset. The result is reported in the next section.

RESULTS

The composites of 850-hPa relative vorticity and 500-hPa relative humidity fields in the WNP for developing disturbances and nondeveloping disturbances for all their time frames and are shown in Fig. 1 and Fig. 2. These two variables are among the key predictors of the nonlinear regression model. Day ‘0’ denotes the day of TC formation. Day ‘-3’ and Day ‘-1’ denote, respectively, three days and one day prior to TC formation. We don’t show Day ‘-2’ here as it generally looks similar to Day ‘-3’. Note that there is little difference in the 850-hPa relative vorticity field between the developing disturbance composite at Day ‘-3’ and the non-developing disturbance composite. Nevertheless, one group eventually develops into a TC 3 days later, whereas another group does not. The developing disturbance group does show a significantly larger relative vorticity at Day ‘-1’(twice as large as the non-developing disturbance group).

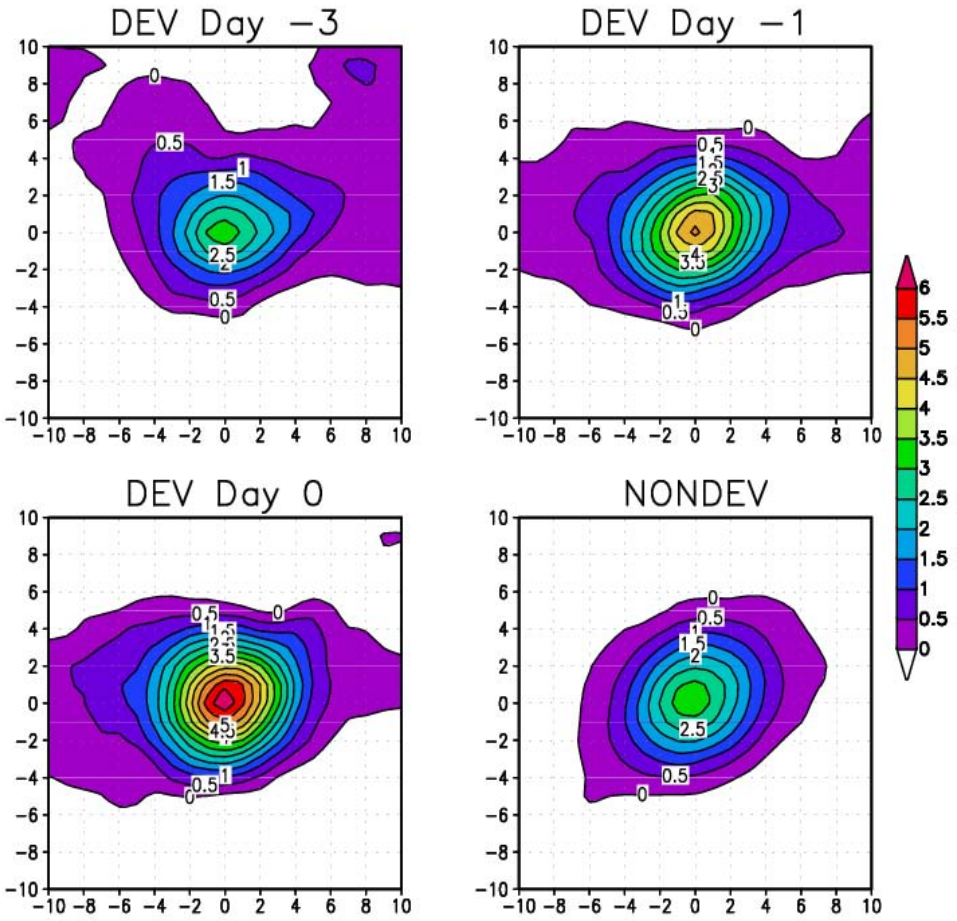

Fig. 1 Composites of the 850 hPa relative vorticity for developing and non-developing disturbances in the WNP. The horizontal domain is a 20^o by 20^o region centered at the maximum 850 hPa relative vorticity. Day 0 is the day when the TCs formed and Day -3 and day -1 are three days and one day prior to TC formation (unit: $10^{-5}s^{-1}$).

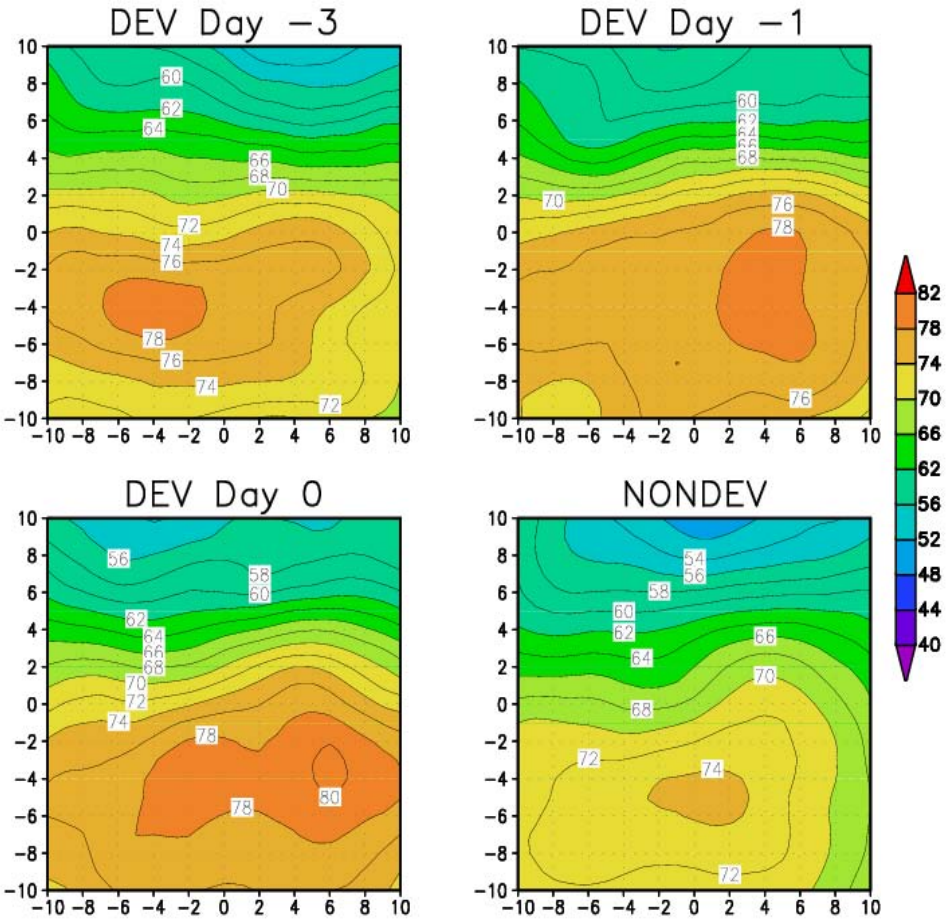

Fig. 2 same as Fig. 1 except that this graphic is for 500 hPa relative humidity (unit: %)

The composite of 500 hPa relative humidity (Fig. 2) show developing disturbances have larger relative humidity even three days prior to TC formation. Comparing the magnitude between these two group shows developing disturbance have roughly 5% more relative humidity than the non-developing group.

Figure 3 shows the in-sample validation of the 24-hour TC probability forecast. Most developing samples are predicted as high probability to develop to TCs and most non-developing samples exhibit near-zero probability to develop. Nevertheless, there are still some developing samples showing low probability and non-developing samples showing high probability.

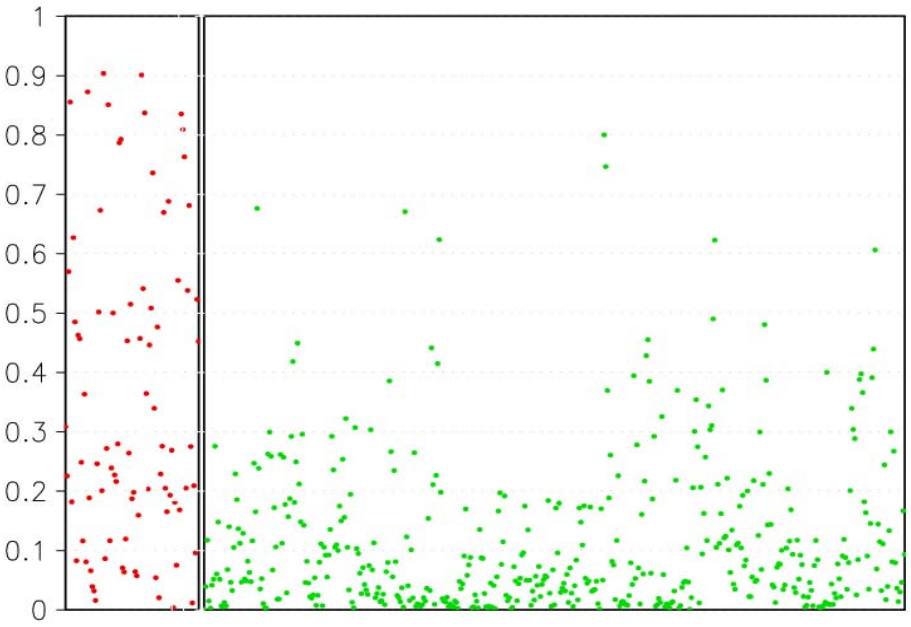

Fig. 3 In-sample validation of 24-hour TC genesis probability forecast model for the WNP. Developing samples are marked as red dots and non-developing samples are green dots. Vertical axis represents TC genesis probability.

The reliability table of the in-sample validation is shown in Table 1. We obtained highly matched forecast probability and observed probability frequency in larger samples groups. The next step will be the application of a step-wise method to optimize the selection of the predictors. It is anticipated that the model performance will be improved once the predictors are optimally selected and combined.

Table 1. In-sample reliability results for forecasts of 24-hour TC genesis

Forecast probability	Observed frequency	Sample size
5%	5.7%	296
15%	11.9%	101
25%	29.0%	62
35%	15.4%	26
45%	44.4%	18
55%	100.0%	9
65%	50.0%	10
75%	80.0%	5
85%	85.7%	7
95%	100.0%	2

IMPACT/APPLICATIONS

The successful completion of this project may provide an operational TC genesis probability forecast system based on the global analysis and forecast fields. Operational TC forecast centers may use this product as a reference for issuing a TC formation alert/warning at a lead of 24-72 hours. This product can also provide guidance on where to place a high-resolution regional model (such as COAMPS) for TC genesis prediction

TRANSITIONS

Results from this project may readily be transitioned to 6.4 projects such as the PMW-120 sponsored "Large-scale Atmospheric Models" and "Small-scale Atmospheric Models" for further operational tests.

RELATED PROJECTS

This project is closely related to a prior NRL 6.2 project on "Predicting tropical cyclone genesis using NOGAPS". Knowledge gained from this project will help to improve the prediction of tropical cyclone genesis.

PUBLICATIONS

Peng, M. S., B. Fu, T. Li, and D. E. Stevens, 2009: Developing versus non-developing disturbances for tropical cyclone formation. Part I: North Atlantic. *J. Atmos. Sci* (submitted, refereed).

Fu, B., M. S. Peng, T. Li, and D. E. Stevens, 2009: Developing versus non-developing disturbances for tropical cyclone formation. Part II: Western North Pacific. *J. Atmos. Sci* (submitted, refereed).